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Directly Measured Physical Function in Cardiac Rehabilitation

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Abstract

Purpose—The Short Physical Performance Battery (SPPB) is a strong predictor for risk of physical disability in older adults. Roughly half of individuals participating in phase II cardiac rehabilitation (CR) are ≥65 years of age, many presenting with low aerobic capacities and may be at increased risk for physical disability.

Methods—The cohort consisted of 196 consecutive patients (136 males), aged ≥65 years, entering CR were prospectively assessed by SPPB. Data were also obtained for age, self-reported physical function (Medical Outcomes Short Form-36), and peak aerobic capacity. Measures were repeated when patients completed CR for those individuals that completed the program.

Results—The average age of patients was 74±0.5 years. At baseline, total SPPB score was 9.7±0.2 (out of 12). Follow-up data was obtained on 133 (68%) patients with a mean improvement of 0.8±0.1 (p<0.0001), which was not clinically significant (≥1 point). Focusing on patients with a low baseline SPPB, 72 subjects scored 9 or below (7.1±0.2) with 45 completing exit measures. Improvements were found in gait speed (0.5±0.1, p<0.0001), chair-stand (1.0±0.1, p<0.0001), and total SPPB (1.6±0.3, p<0.0001) in this more disabled group. Measures of VO_{2peak} was significantly reduced in the low SPPB group (13.5±0.4 vs 17.5±0.4 ml/kg/min, p<0.0001). VO_{2peak} (R^2=26%, p<0.0001) and self-reported physical function score (R^2= 5%, p=0.02) were the only multivariate predictors of baseline SPPB.

Conclusion—For patients who enter CR with low SPPB scores (37%) significant improvements in physical function are noted, largely explained by improved walking speed and leg strength (chair-stand).

Brief Abstract

The Short Physical Performance Battery (SPPB) is a strong predictor for risk of physical disability in older adults. For older patients who enter cardiac rehabilitation with diminished physical function (37%), significant improvement is noted in walking speed and leg strength (chair-stand) following completion of an exercise program.

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Introduction

Despite well documented effects of cardiac rehabilitation (CR) on mortality and aerobic capacity,[1,2,3,4,5] little is known regarding its effect on directly measured physical function. The CR demographic often consists of elderly patients with low aerobic fitness,[6,7] both significant risk factors for disability with the mean age of participants at many programs approaching 65 years.[7] Additionally, rates of frailty in community-dwelling adults with cardiovascular disease range from 10–60%, indicating that many CR participants may be at increased risk of disability.[8,9]

The Short Physical Performance Battery (SPPB) was developed to assess disability risk through performance in balance, gait speed, and repeated chair-stands.[10] Better performance in individual components or total score is associated with lower rates of mortality, disability, hospitalizations, and nursing home admissions.[10,11,12,13] The SPPB has been validated in multiple populations[12,14] and is sensitive to major clinical events including hospitalization for hip fracture, stroke, congestive heart failure, and myocardial infarction. While structured exercise has been shown to result in modest improvements on the SPPB in a healthy population,[15] there is limited information regarding physical function and the SPPB in cardiac patients in a Phase II CR program. Additionally, there are conflicting reports as to whether long-term maintenance programs following CR produce benefits in this domain. One study found no change in SPPB following 1.6 years of a maintenance exercise program[16] while another resulted in improvements at 1 year in elderly frail patients who incorporated strength, flexibility, balance, and coordination exercises in addition to aerobic exercise.[17]

Of studies that addressed the effect of CR on physical function, most employ self-reported questionnaires for their analysis.[18,19] Therefore, we sought to directly measure physical function in an older CR population utilizing the SPPB and its response to exercise training. We hypothesize that completion of phase II CR will improve performance on the SPPB.

Methods

Subjects

The study sample included consecutive patient's aged 65 years or older entering an outpatient phase II CR program. Study data was prospectively collected from January 2011 to October 2013. During an initial visit, data was collected on age, sex, body weight, height, aerobic capacity, handgrip strength (kg), self-reported physical fitness (Medical Outcomes Study Short Form-36 (MOS SF-36)),[20] and depression scores (Geriatric Depression Questionnaire).[21] The primary cardiac diagnosis at entry into CR was also recorded including: coronary artery bypass graft surgery; myocardial infarction; angina treated with a percutaneous intervention alone (without MI); angina treated medically; congestive heart failure, and heart valve replacement/repair surgery.

SPPB

The SPPB was performed as previously described.[10] The SPPB is composed of three tasks assessing an individual's balance, gait speed, and ability to stand from a chair (chair-stand).

The balance component required subjects to hold a standing position (side-by-side, semi-tandem, tandem) for 10 seconds each. Gait speed was measured over a 4 meter course at a usual walking pace. Chair-stand was the time required to rise from a seated position 5 times. Scores for each domain range from of 0–4 for a total score of 0 to 12. Scores reflect quartiles of the original study population, i.e. 1<25th percentile, 4>75th percentile. A higher score indicates better physical function with lower scores sequentially increasing the likelihood of future disability. The initial SPPB was performed within the time frame of the first 4 exercise sessions and the exit analysis was obtained during the final exercise session or prior to an exit ETT.

Exercise Tolerance Test

At entry and exit from the CR program, patients performed a symptom limited treadmill exercise tolerance test (ETT) to determine peak aerobic capacity (VO_{2peak}) in mL $O_2 \cdot kg^{-1} \cdot min^{-1}$. Treadmill protocols included the Bruce, modified-Balke, and modified-Naughton, depending on an initial estimation of fitness, and continued until volitional exhaustion, progressive angina, or other untoward findings that necessitated termination. Individuals performed the same exercise protocol at baseline and exit from CR. Expired gas analysis was measured continuously throughout the ETT with a Medgraphics Ultima CPX (St. Paul, Minnesota). The highest average 30-second value for VO_2 was defined as the VO_{2peak}. Calibration was performed for each test as described previously.[6] Quality control is performed according to published guidelines.[22]

For patients completing an entry ETT without expired gas analysis (i.e. at referring private cardiologist office), VO_{2peak} was estimated using the Ades nomogram.[6] The regression equation utilizes age and treadmill time and has been validated in clinical cardiovascular populations entering CR as more accurate than estimating oxygen consumption based on treadmill time alone.[23]

Exercise Protocol

The exercise training program generally consisted of 3 sessions per week of aerobic and strength training to a total of 36 sessions. Patients were monitored during training sessions, and exercise intensity was adjusted to maintain participant heart rate (HR) in the range of 70% to 85% of the peak HR obtained on the entry ETT and/or a Borg scale for rating of perceived exertion between “fairly light” and “hard” (11–15 on a scale of 6–20). Typically, exercise training sessions comprised 25 minutes on the treadmill; and 8 minutes on 3 other implements including elliptical trainers; upright and seated steppers; and cycle, arm, and rowing ergometers. Resistance training included both upper and lower extremity exercises with most patients performing 1 set of 10 repetitions with a subjective rating of “hard.” Patients were encouraged to exercise 1–2 times per week on their own to a total of 3–5 exercise sessions per week.

Statistical Analysis

The cohort was stratified into a higher (≥10 total SPPB) and lower (≤9 total SPPB) performing group for further analysis according to baseline performance. Between-group comparisons at baseline and following CR were performed with ANOVA and chi^2 tests

(IBM SPSS Statistics version 22). Paired t-tests were used to compare changes following CR. Stepwise linear regression was utilized for prediction of baseline SPPB scores. Statistical significance was set at the level of $p<0.05$. All data are reported as mean ± SEM.

Results

Baseline Demographics

Baseline demographics were obtained for 196 subjects (Table 1) and these characteristics did not differ by index diagnosis (not shown, p=NS).

Baseline SPPB scores

Average total SPPB score at entry to CR was 9.7±0.2 (out of 12) and multiple regression revealed a significant correlation between SPPB and VO_{2peak} (r=0.508). Further analysis found 124 (63%) patients scored 10 or higher for total SPPB, thus indicating these patients were unlikely to have significant near term risk of disability and may display a ceiling effect in terms of changes with exercise training.

Training Effect

Following CR, 133 subjects completed follow-up measures with no change noted for balance (3.5±0.1vs3.6±0.1, p=0.25). Statistically significant improvements were observed for gait speed (3.7±0.1vs3.9±0.0), chair-stand (2.7±0.1vs3.3±0.1), and total SPPB (9.9±0.2vs10.7±0.2) (all p<0.0001) though none of these overall changes were clinically significant (≥1 unit) as determined by previous studies (Figure 1).

Follow-up performance measures were not obtained for 63 patients due to discontinuation of CR for medical or personal reasons. When compared to those who completed exit evaluations, baseline measures for non-completers were lower for VO_{2peak} (15.0±3.2vs16.8±4.7mL/kg/min, p=0.015), MOS SF-36 (54±23vs64±23, p=0.05), and total SPPB (9.2±2.4vs9.9±2.3, p=0.034) with trends towards poorer chair-stand performance (2.4±1.2vs2.7±1.3, p=0.061) and higher weight (185±39vs174±33lbs, p=0.052). Additionally, non-completers attended significantly fewer CR sessions (19±13vs32±8, p<0.0001). Of the 63 non-completers, 36 (57%) scored 10 or above and 27 (43%) 9 or below for total SPPB, making it unlikely that SPPB scores influenced CR participation.

Focus on Low SPPB Scores

When patients were stratified by baseline SPPB, 72 subjects scored at 9 or less (low group, 7.1±0.2) with 45 completing exit measures. Improvements were found for gait speed (+0.5±0.1, p<0.0001) and chair-stand (+1.0±0.1, p<0.0001) in addition to a clinically significant improvement in total SPPB (+1.6±0.3, p<0.0001) in this higher risk group. 124 patients scored 10 or greater at baseline (high group, 11.2±0.1), suggesting a low risk of future physical disability, with no meaningful improvements found at exit in this group (n=88).

Comparisons Between High and Low Scoring Groups

When comparing changes in physical function between the high and low scoring groups, greater improvements occurred in the low scorers for all measures except balance, which was not affected by exercise (Figure 2). VO_{2peak} was significantly reduced in the low scoring subgroup at baseline (13.5±0.4 vs 17.5±0.4 mL/kg/min, p<0.0001). Additionally, low total SPPB scores were associated with older age and decreased handgrip strength and self-reported physical function (Table 1). Incidence of diagnoses did not vary between groups indicating that baseline differences were not the result of cardiac status (i.e. surgery).

When analyzing patients with a VO_{2peak} greater than 5 metabolic equivalents (METs, approximately 17.5mL/kg/min) to those less than 5 METs, total SPPB scores were 11.1±0.2 vs 9.5±0.2 respectively (p<0.0001). Furthermore, balance (p<0.0001), gait speed (p=0.028), chair-stand (p<0.0001), and total SPPB (p<0.0001) were significantly higher in the high fitness group. VO_{2peak} (R^2= 26%) and sf-36 (R^2= 5%) were the only significant independent predictors of baseline SPPB by multiple regression. Additionally, 91% of patients with a baseline aerobic fitness greater than 5 METs had total SPPB scores of 10 or above as compared to 58% of patients below 5 METs (Figure 3).

Discussion

A significant percentage (37%) of participants ≥65 years entering phase II CR score low on the SPPB (≤9), presumably placing them at higher risk of disability over four years.[10] While these patient's baseline SPPB scores were lower, they experienced significant improvement following participation in a phase II CR exercise program. The gains observed in physical function are explained primarily by improvements in walking speed and leg strength (chair-stand), both of which are impacted through aerobic and resistance training in the CR setting whereas balance did not improve.

The majority of older patients entering CR do so with relatively higher levels of physical function as measured by the SPPB and, likely, with a relatively low risk of disability. Previous research indicates a substantial change in physical function is indicated by increases in gait speed (0.10m/s) and total SPPB (>1point).[24] While we found statistically significant improvement in overall scores, the changes in gait speed, chair-stand, and total SPPB were not clinically significant in our overall population. Therefore, there is likely a ceiling effect for high functioning patients where no improvements can be seen when utilizing the SPPB. This could explain why Mandic et al. found no improvements in their follow-up of CR patients as the average SPPB of their population was 11.5 points at baseline.[16] Additionally, their participants may have experienced significant improvements during CR, similar to our population, which was then maintained through a long-term exercise program. Focusing on lower functioning patients (≤9) demonstrated significant improvements in gait speed, chair-stand and total SPPB but not balance. Although performance on the balance section remained unaffected by CR, the result is consistent with previous literature specifying that the SPPB balance component is less sensitive to change than chair-stand, gait speed, and handgrip strength after an exercise program[25,26] although it may improve after a longer duration and more intensive strength training program.[27] It should be noted that while there were baseline differences between the high and low groups in age (73vs77 years) and handgrip strength (32vs26kg), no differences were found in weight or BMI. It is therefore difficult to determine the degree to which age or age-related muscle loss influenced baseline SPPB scores as neither was a significant predictor in the multiple regression model.

An aerobic capacity less than 5 METs (approximately $17.5 mLO_2*kg^{-1*}min^{-1}$) classifies CR participants at moderate risk for cardiac events during exercise participation.[28] Therefore, the differences found in VO_{2peak} between the high and low scoring groups provide evidence that lower physical function may place CR patients not only at an increased risk of disability, but may be indirectly associated with increased risk of cardiac events as well. The SPPB appears to be less useful in CR participants with better aerobic fitness as higher VO_{2peak} was associated with high SPPB scores (11.1 points). We found that 91% of patients with aerobic capacities greater than 5 METs scored high on the SPPB, which corresponds with completion of 3 minutes on the Bruce, 6 minutes on the modified Balke, or 10 minutes on the modified Naughton ETT protocols. As aerobic consumption measures incorporate components of walking speed, muscle mass, and muscular performance (strength and endurance) among other factors, the ETT may provide similarly useful measures of physical function as the SPPB. In support of this concept, the 6 minute walk test was deemed highly reliable and capable of discriminating between good and high functioning individuals[25] even though it is a submaximal test for aerobic function. Therefore, an alternative to measuring SPPB to identify low physical function could be utilizing an ETT to prescreen for further testing. Additional benefits of employing an ETT include objectively determining aerobic capacity, peak heart rate, and target heart rate zones as well as screening for ECG changes and cardiovascular symptoms.

Our observations have the potential to be applied to additional frail cardiovascular patients. Frailty, as defined by gait speed, is associated with a higher 6-month mortality in multivessel acute coronary syndrome (<0.62m/s)[29] as well as a 3-fold increase in post-operative mortality following cardiac surgery (<0.83m/s).[30] Therefore CR may serve to facilitate surgical recovery in older patients and improve long term outcomes.[26] Our data supports this view as surgical patients SPPB scores improved similarly to other diagnosis following CR. Furthermore, we have previously demonstrated that surgical patients display 18–20% and 5–10% improvements in VO_{2peak} and handgrip strength respectively.[31,32] Congestive heart failure can lead to cardiac cachexia[33,34] and is known to alter skeletal muscle function through changes in myosin cross-bridge interaction.[35,36] This skeletal muscle dysfunction can be mitigated through strength training,[34] underscoring the importance of including resistance training in CR for older patients in general.[27] Because our population only included 3 primary congestive heart failure patients, we cannot speak to the efficacy of CR to improve SPPB in this cohort.

Our study was limited by its nonrandomized observational nature in a single clinical setting. Additionally, aerobic capacity was indirectly determined in 43% of the subjects. The method of measurement is not likely important as our main outcome was SPPB, the majority of patients underwent expired gas analysis testing, and the Ades equation has been confirmed to be accurate in the CR population.[23] Furthermore, aerobic capacities were similar regardless of direct or indirect measurement (15.8vs16.4). Nonetheless, we found that most older patients enter CR with high SPPB scores and exercise training clearly improves physical function in patients with low baseline values. Additional follow up is required to determine if increases seen in SPPB scores lead to lower rates of physical disability, nursing home admissions, or mortality in an older CR population.

In summary, measurement of the SPPB in older CR patients entering CR was moderately useful from a clinical point of view although a baseline ETT was a useful proxy for SPPB score and thus, risk of disability. After conditioning, when older subjects were stratified by baseline SPPB, CR resulted in an improvement in walking speed, chair stand and total SPPB score in subjects who scored 9 or less when entering CR. Stratifying by fitness, 42% of older patients with aerobic capacities below 5 METs exhibited lower performance (≤9 points) on the SPPB. Rather than screening all older patients, it may be advantageous to target those with a functional capacity below 5 METs for additional testing with the SPPB.

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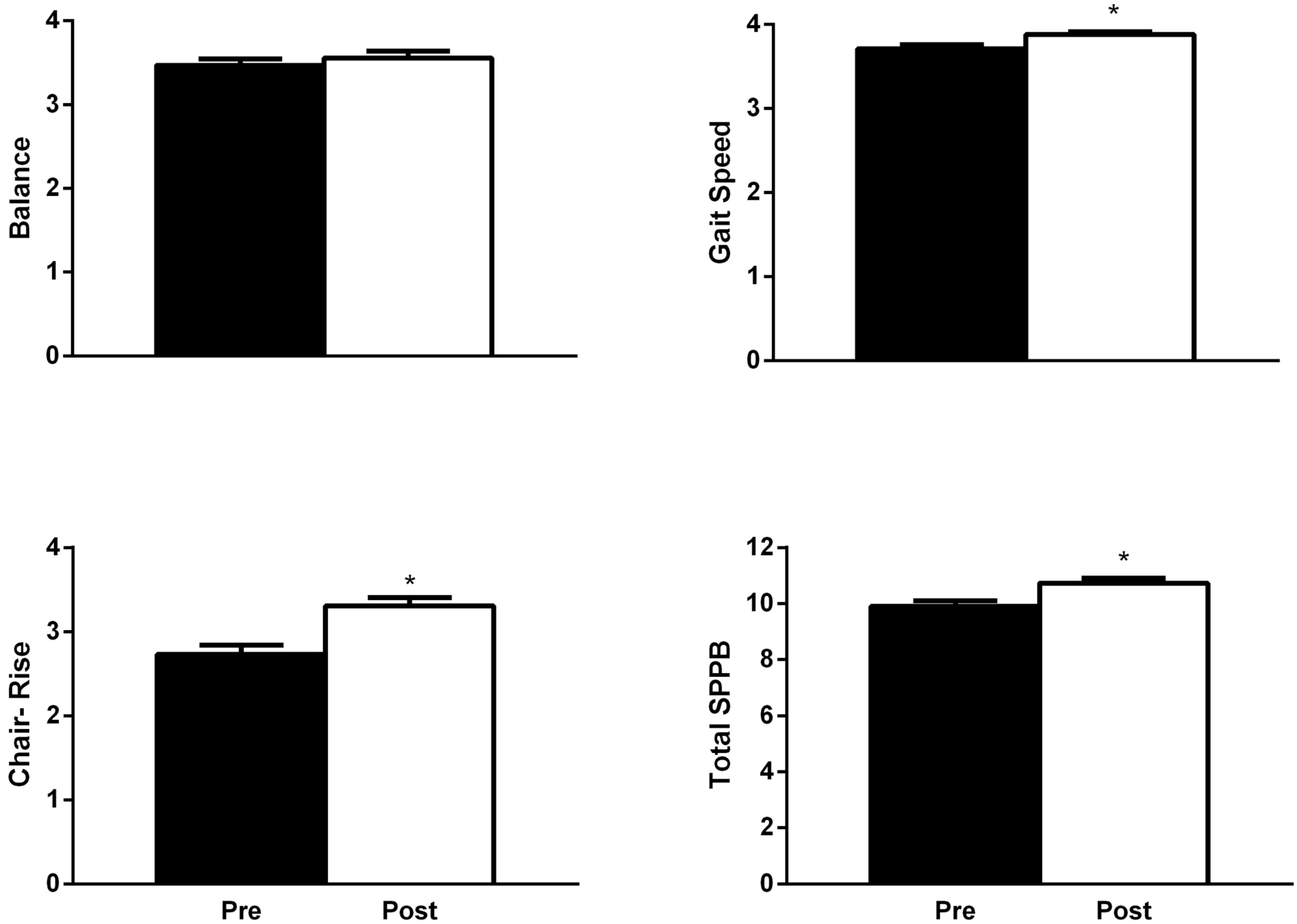

Figure 1.

Short Physical Performance Battery (SPPB) scores at entry to and exit from cardiac rehabilitation. Data are mean ± SEM. * indicates statistical significance between pre and post scores at $p<0.0001$.

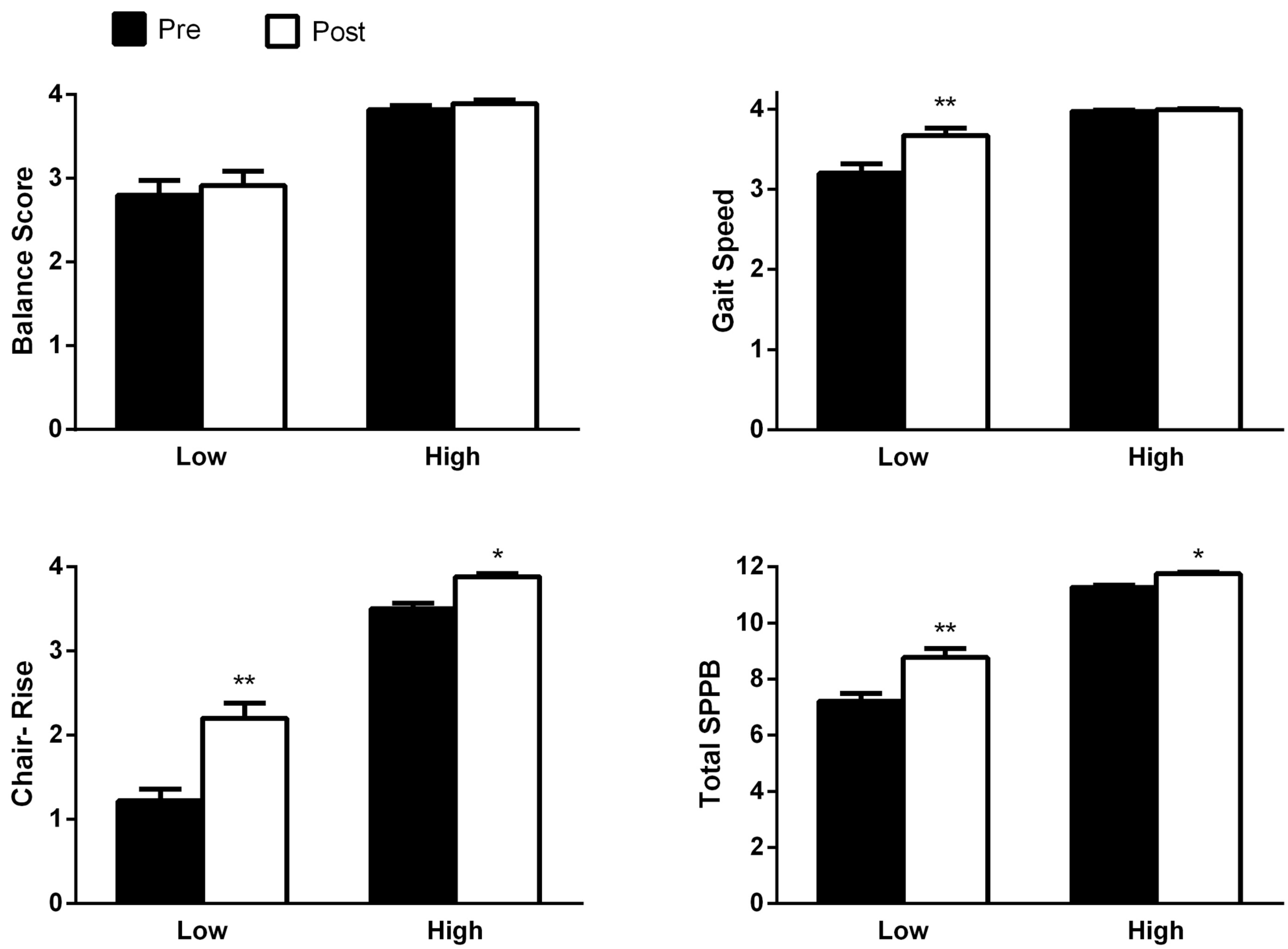

Figure 2.

Change in Short Physical Performance Battery (SPPB) scores with cardiac rehabilitation participants stratified into lower (≤9) and higher (≥10) scoring groups according to baseline performance. Data are mean ± SEM. * indicates within group statistical significance at p<0.0001. ** indicates both within and between group differences in response to exercise training at p<0.0001.

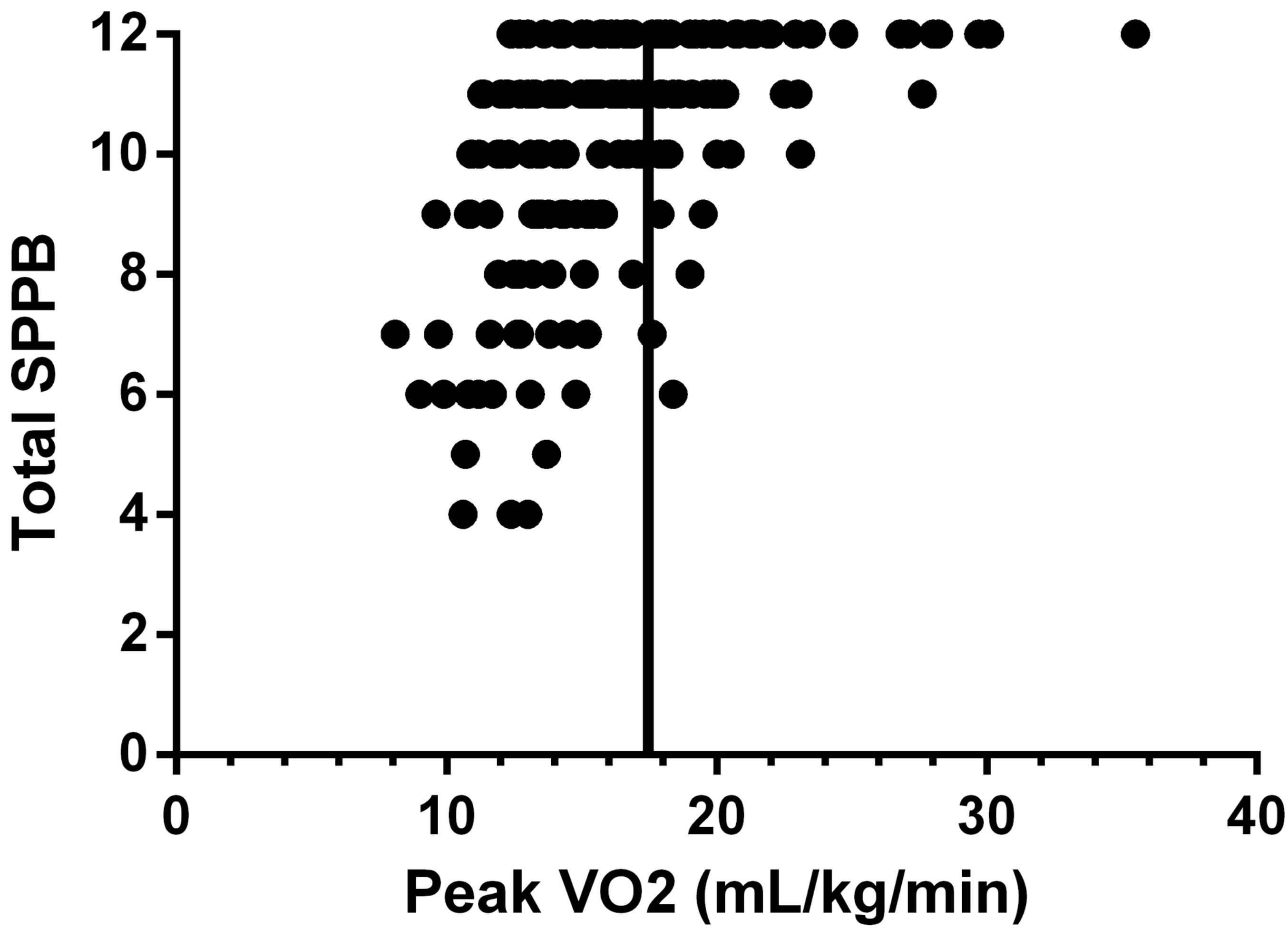

Figure 3.

Relationship between Short Physical Performance Battery (SPPB) and VO_{2peak} at baseline. The vertical bar indicates an aerobic capacity of 5 METs (approximately 17.5 $mLO_2*kg^{-1}*min^{-1}$)

Table 1

High vs Low SPPB Group Comparisons.

	Total	Low	High	P value
n (M/F)	196 (136/60)	72 (43/29)	124 (93/31)	
Sessions	28 ± 1	28 ± 1	28 ± 1	0.78
Age (yr)	74 ± 1	77 ± 1	73 ± 1	<0.0001
Body mass (kg)	80.7 ± 1.1	80.0 ± 1.8	81.4 ± 1.4	0.60
Body mass index (kg/m^2)	28.3 ± 0.4	29.1 ± 0.8	27.8 ± 0.4	0.12
Handgrip Strength (kg)	30 ± 1	26 ± 1	32 ± 1	<0.01
MOS SF-36 Physical Function	61 ± 2	52 ± 3	67 ± 3	<0.01
Geriatric Depression Score	2.7 ± 0.2	2.8 ±0.3	2.6 ± 0.3	0.57
Peak VO_2 ($mLO_2*kg^{-1}*min^{-1}$)	16.3 ± 0.3	13.5 ± 0.4	17.5 ± 0.4	<0.0001
Index Diagnosis				
Coronary Artery Bypass Grafting	26% (50)	22% (16)	27% (34)	
Myocardial Infarction	31% (61)	29% (21)	32% (40)	
Percutaneous Coronary Intervention	27% (52)	25% (18)	27% (34)	0.51
Medical Therapy/Stable Angina	1% (2)	1% (1)	1% (1)	
Congestive Heart Failure	2% (3)	1% (1)	2% (2)	
Valvular Heart Disease	14% (28)	21% (15)	10% (13)	

Data are mean ± SEM. Depression score >5 demonstrates significant symptoms of depression.